

Laser-produced plasma EUV source around 6.7-6.8 nm for future semiconductor lithography

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CORE

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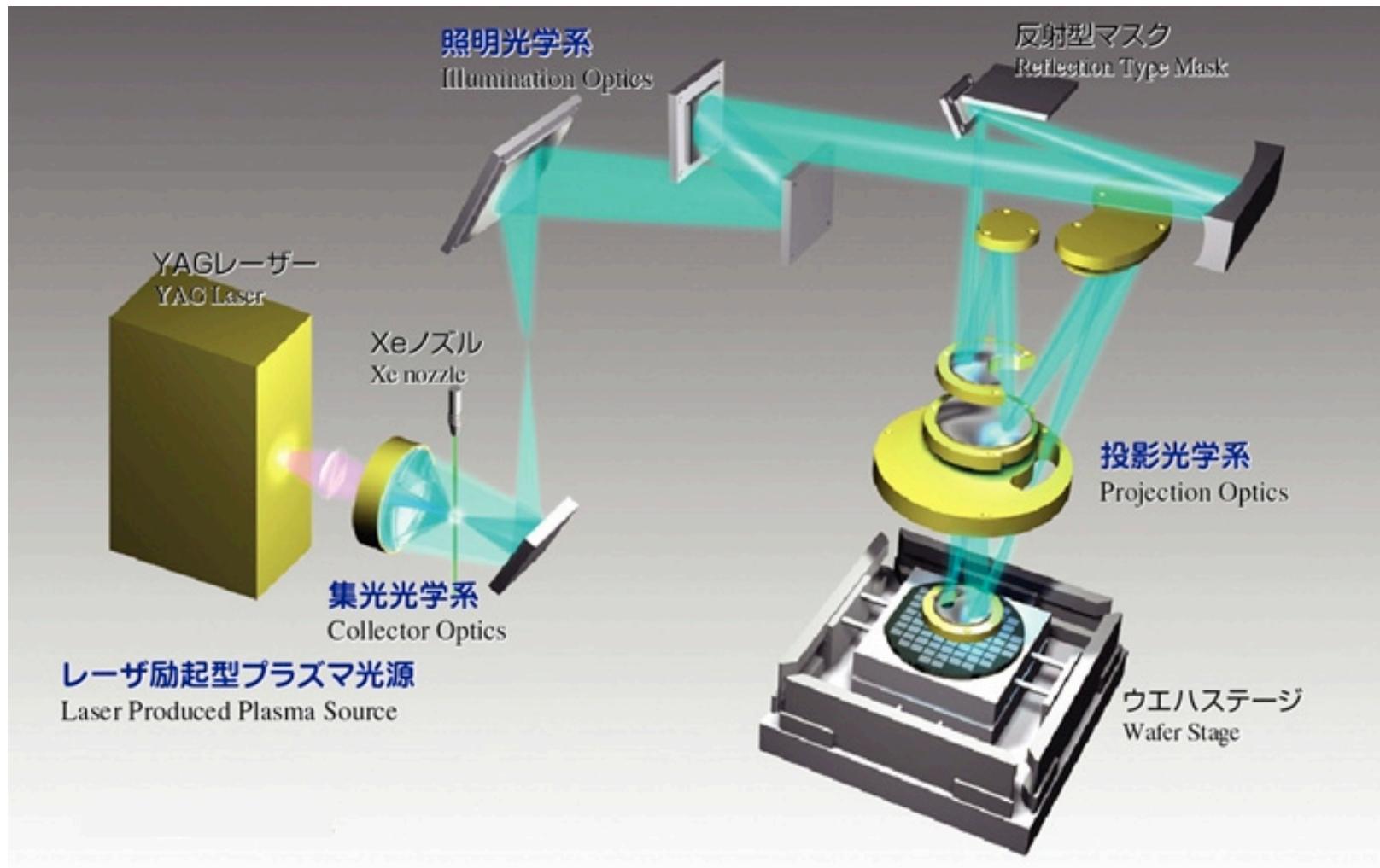
³Forschungszentrum Dresden

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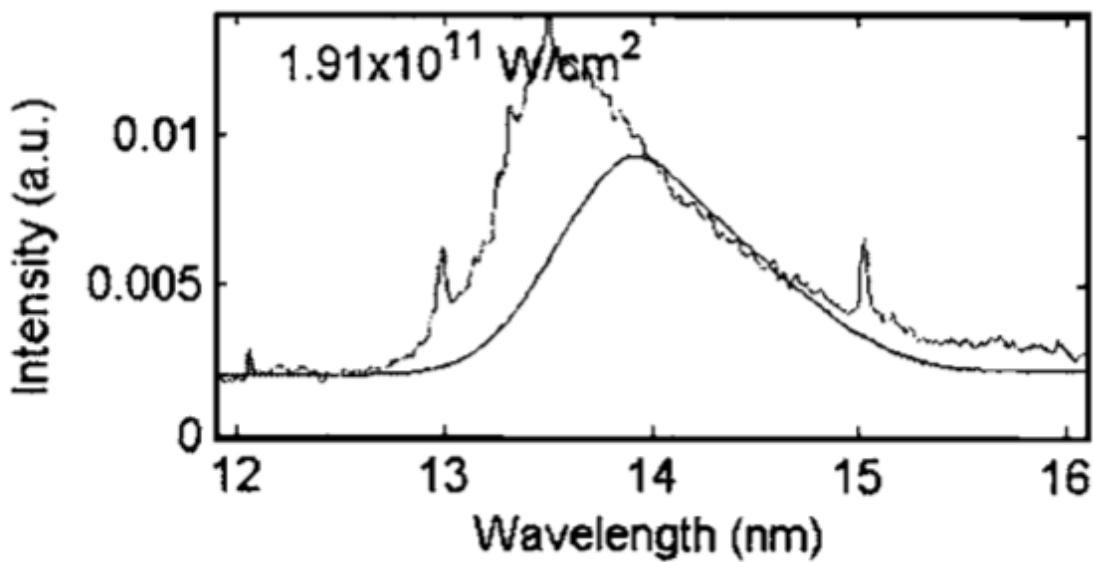
2010 International Symposium on Extreme Ultraviolet Lithography
Kobe International Conference Center, Japan
October 17-20, 2010

Extreme ultraviolet lithography



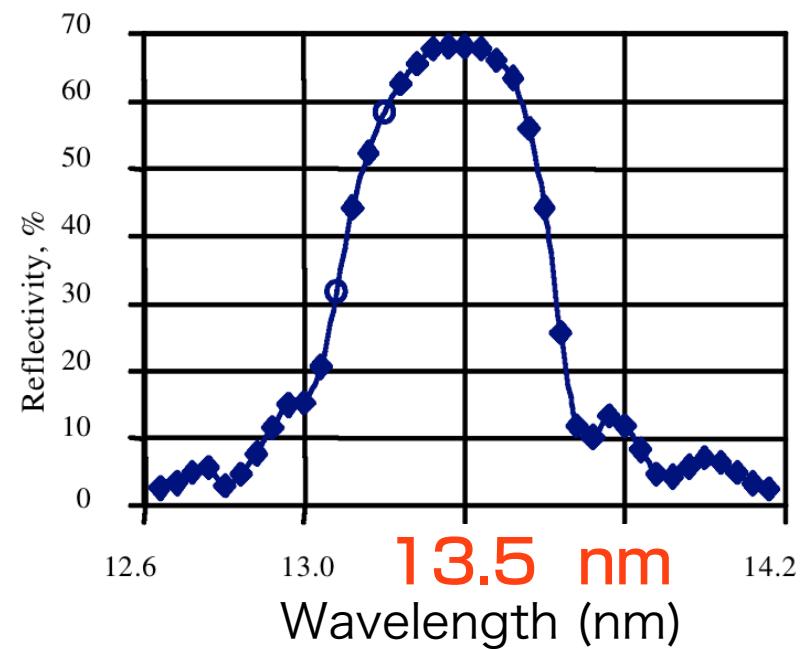
Next generation: 13.5 nm

13.5 nm: Sn plasma

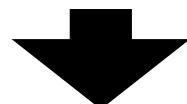


J. White *et al.*, Appl. Phys. Lett. **98**, 113301(2005)

Mo/Si mirror



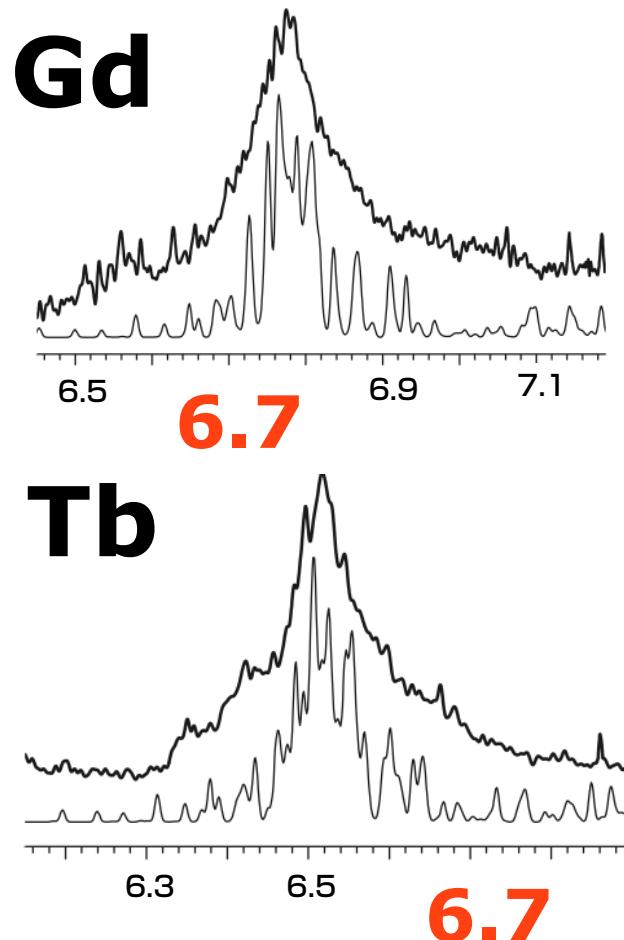
S. S. Andreev *et al.*, CEJP., **1**, 191(2003)



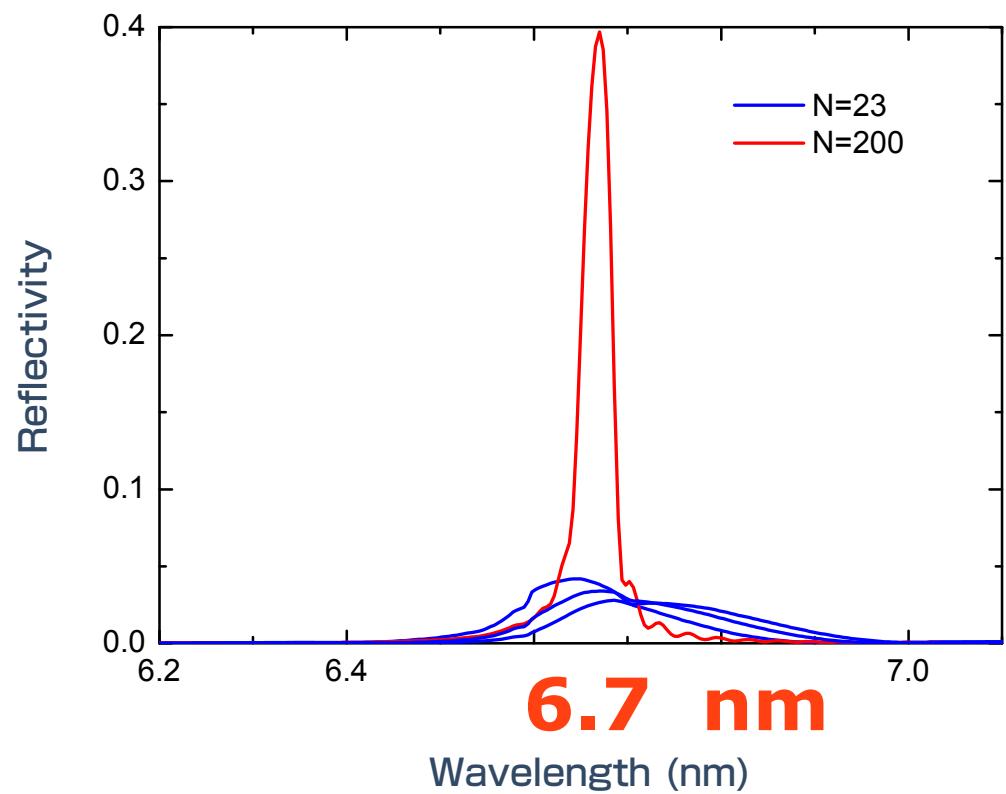
Put to practical use in 2012

What's next?

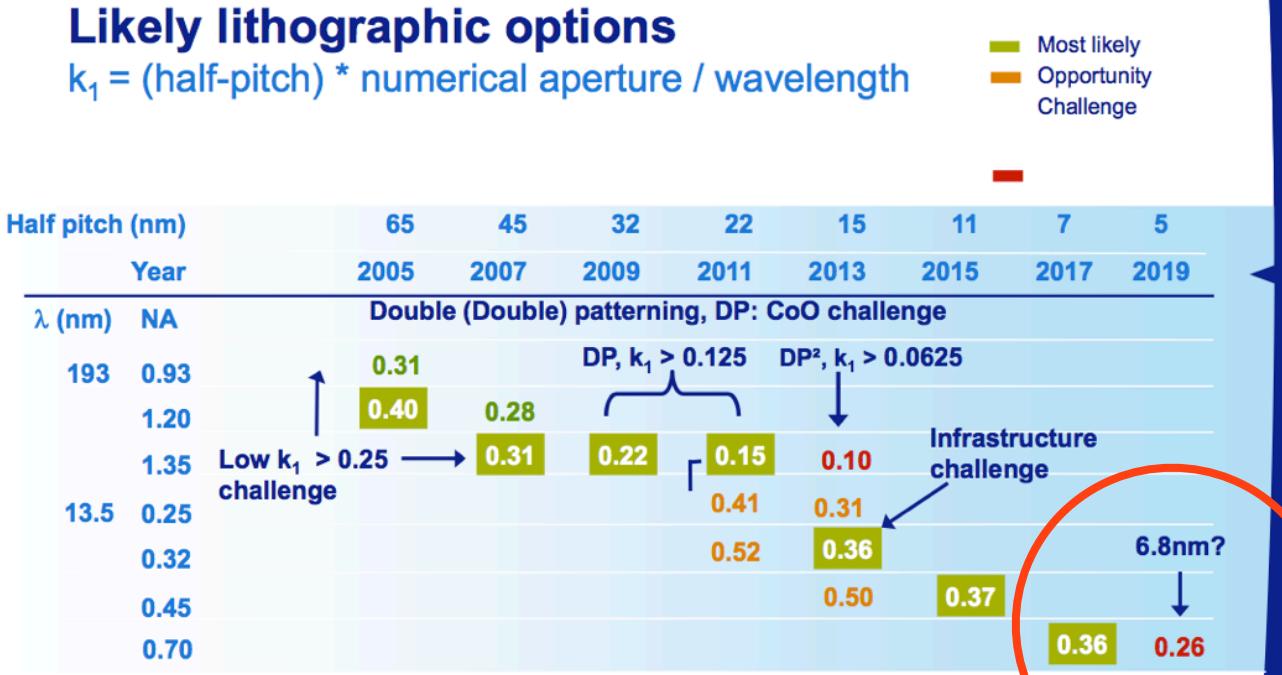
6.7 nm: Gd, Tb plasmas



Mo/B₄C mirror



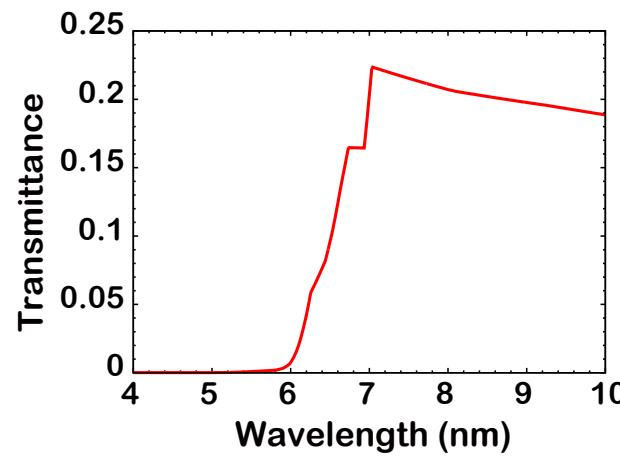
Early evidence - ASML



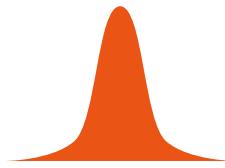
Objective

We characterize
**EUV emission from
Laser-produced plasmas
around 6.5-6.7 nm using Gd and Tb**

Experimental setup



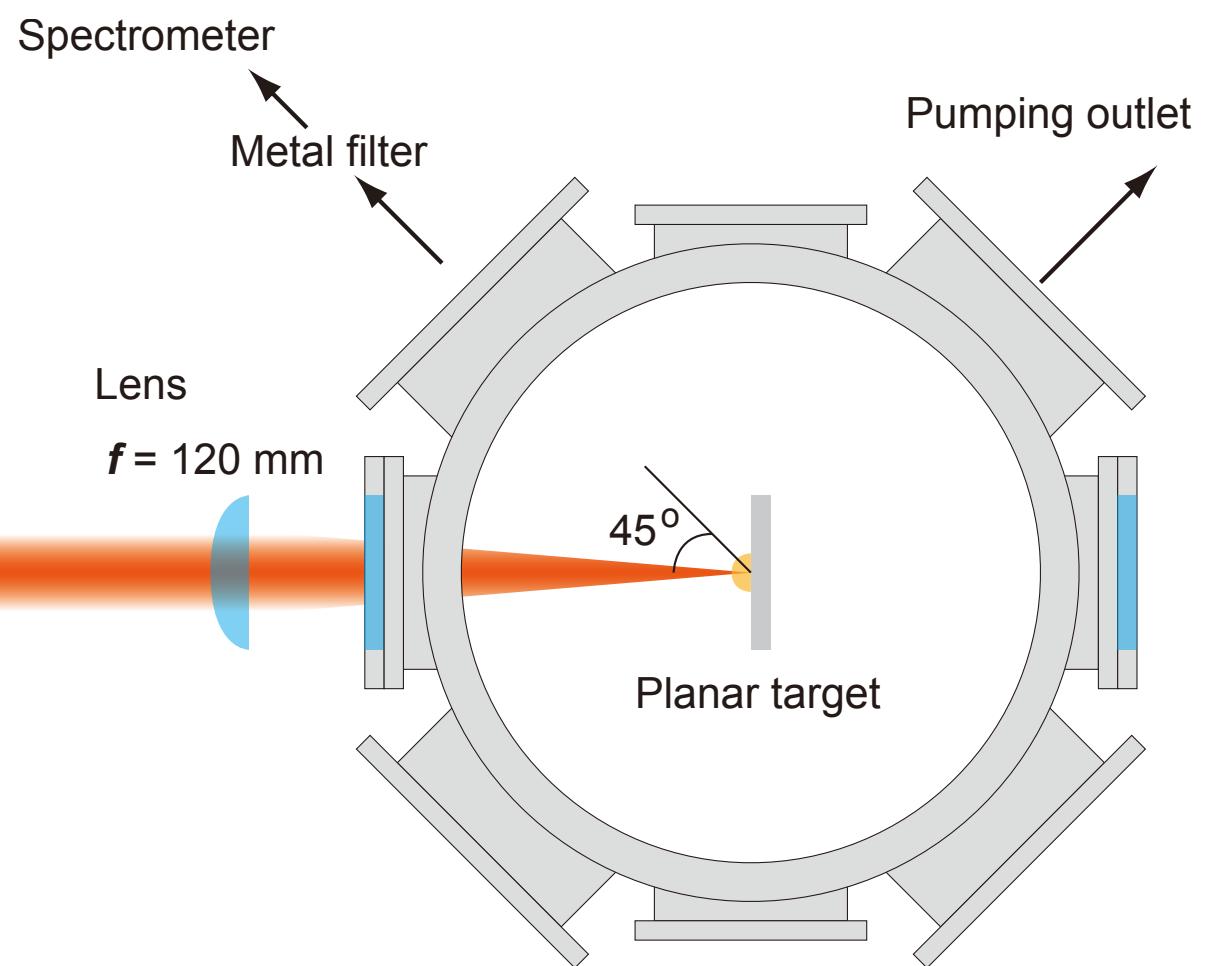
Nd: YAG Laser



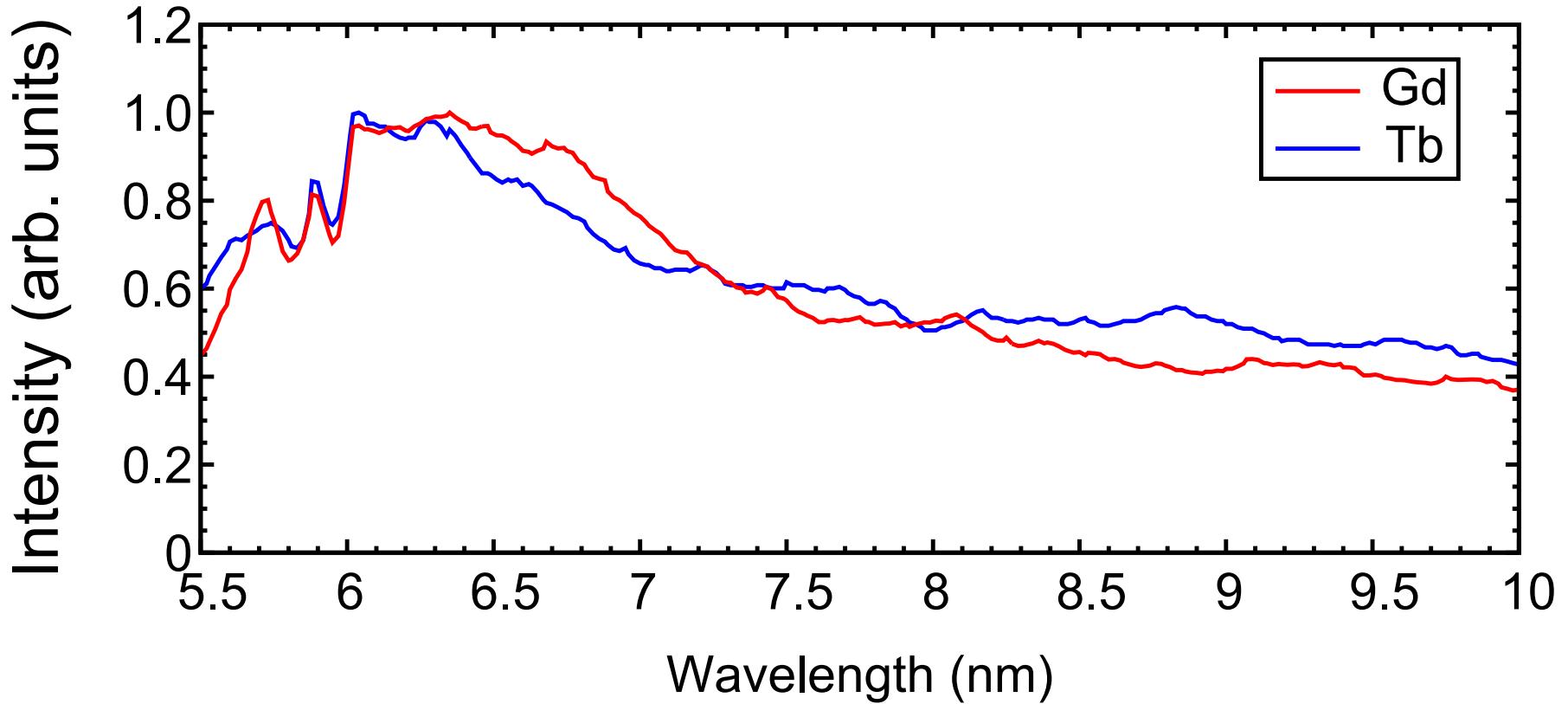
Laser energy: 2 J

Wavelength: 1064 nm

Pulse width: 10 ns

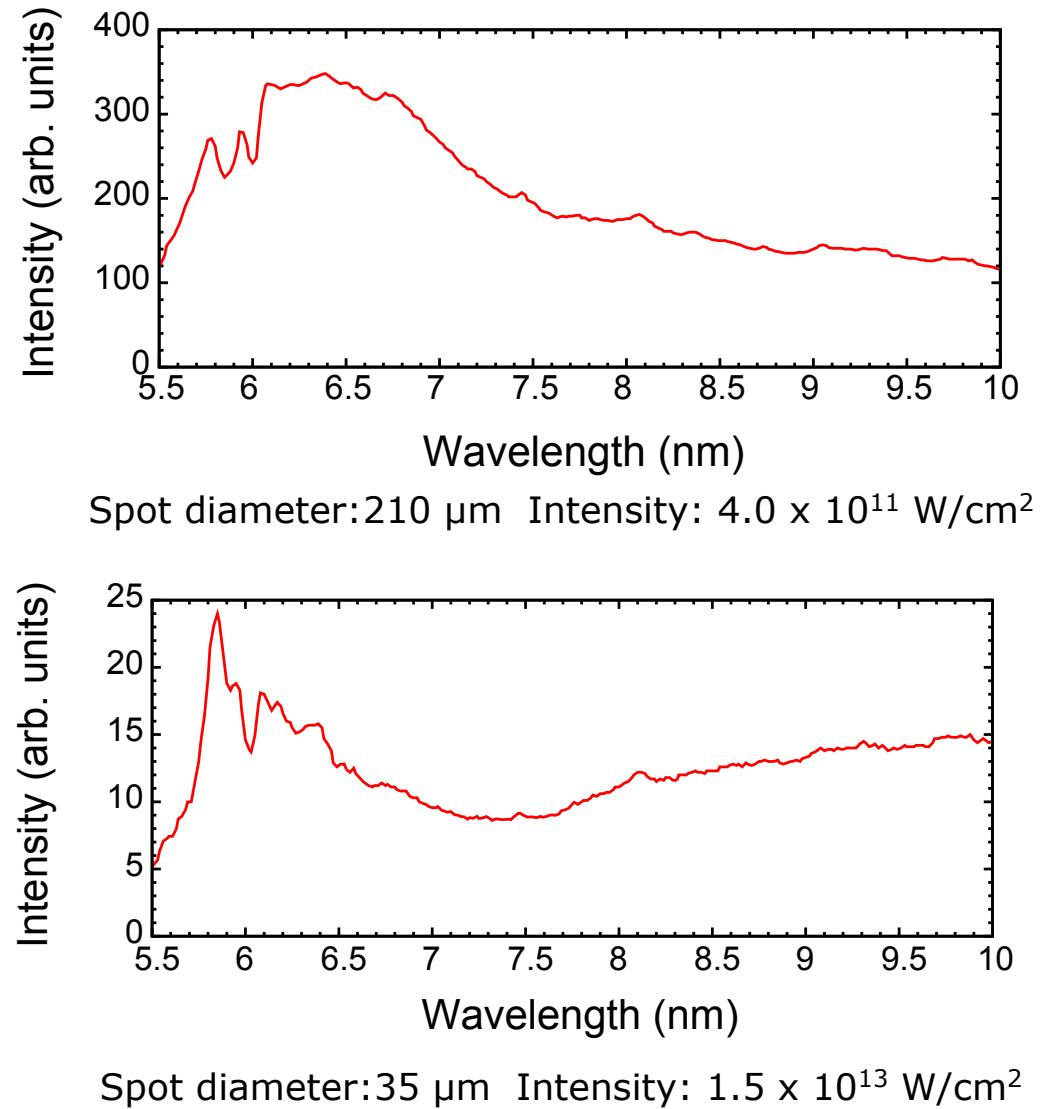
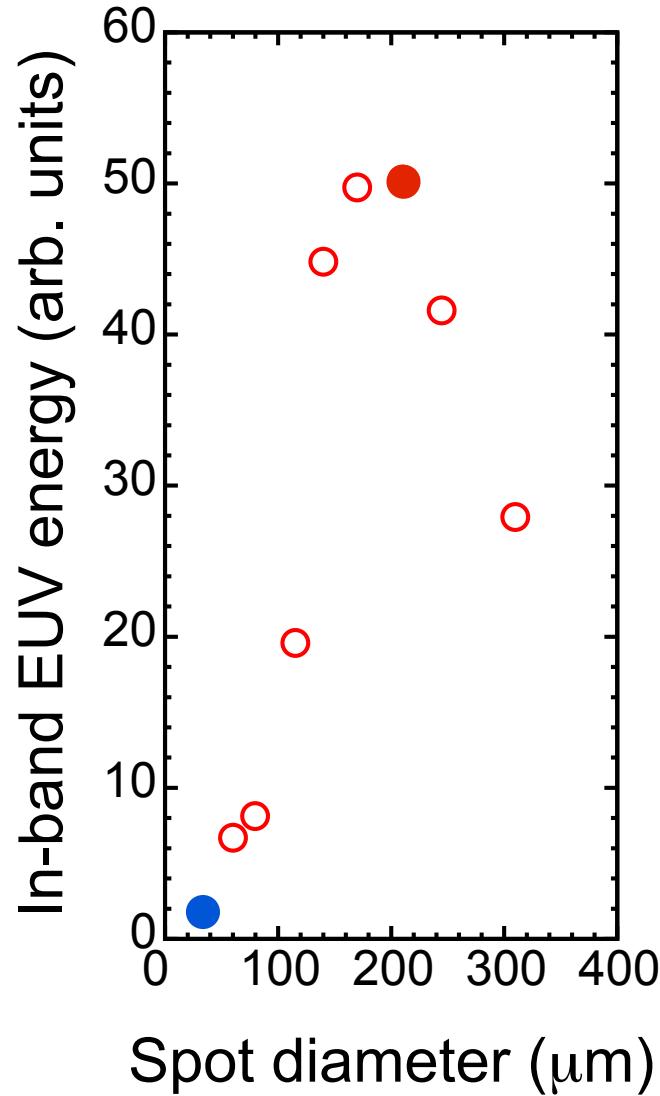


Spectra of EUV emission from Gd and Tb plasmas

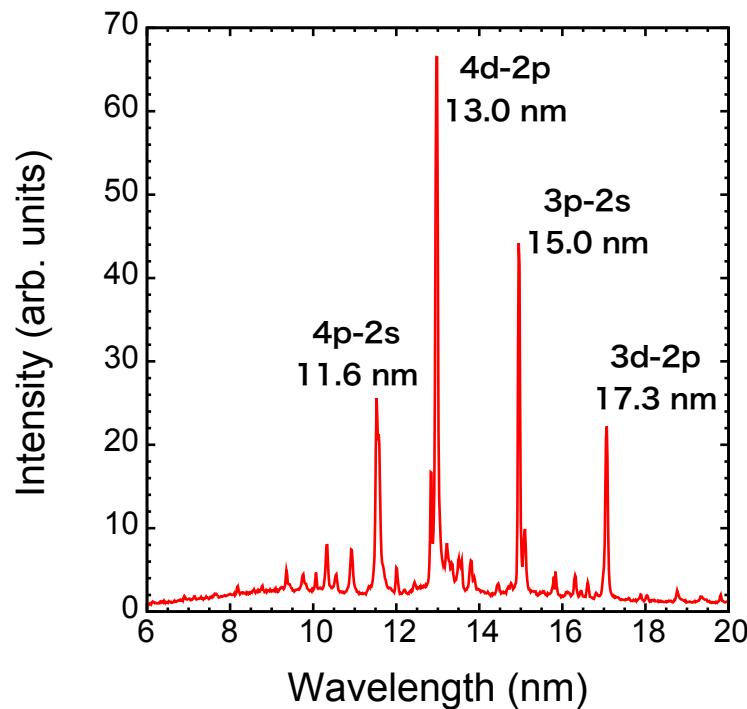


Spot diameter: 210 μm
Laser intensity: $4.0 \times 10^{11} \text{ W/cm}^2$

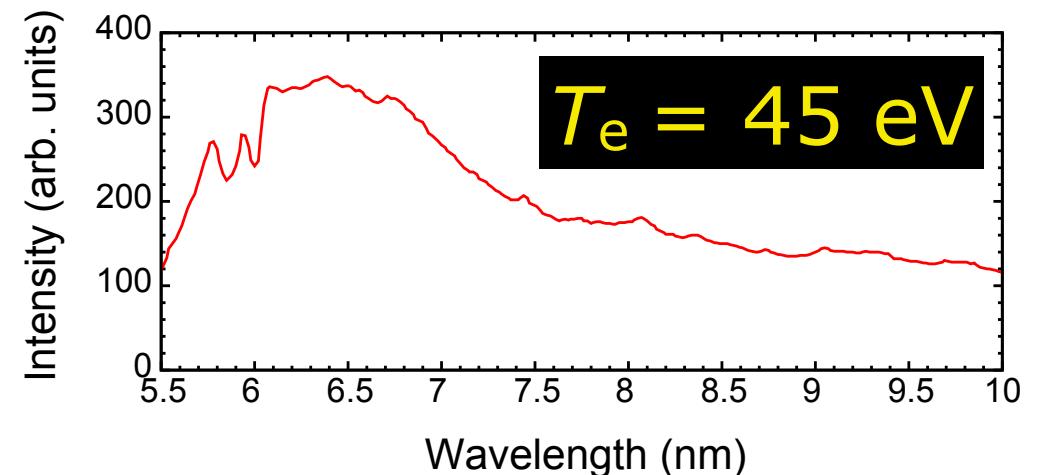
In-band- EUV energy vs Spot diameter



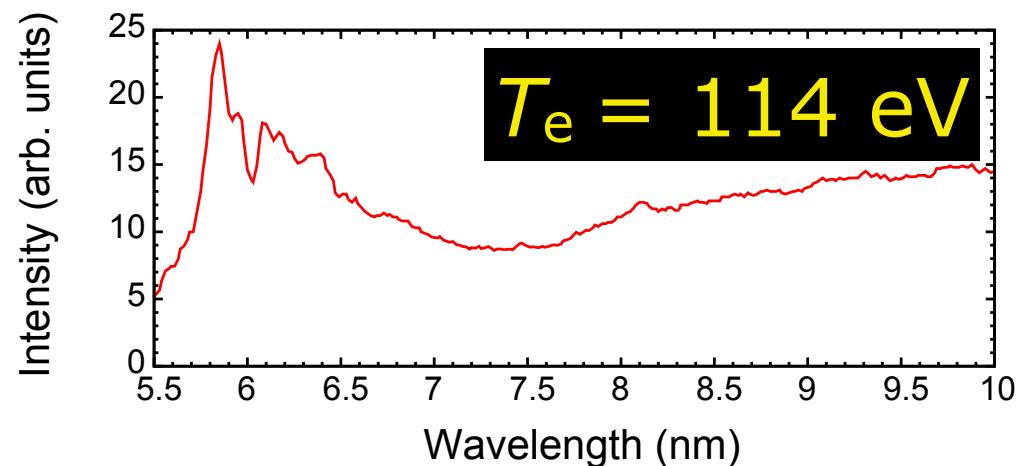
Evaluation of electron temperatures



$$T_e \propto \frac{\Delta E}{\ln(I_1 \lambda_1 / I_2 \lambda_2)}$$

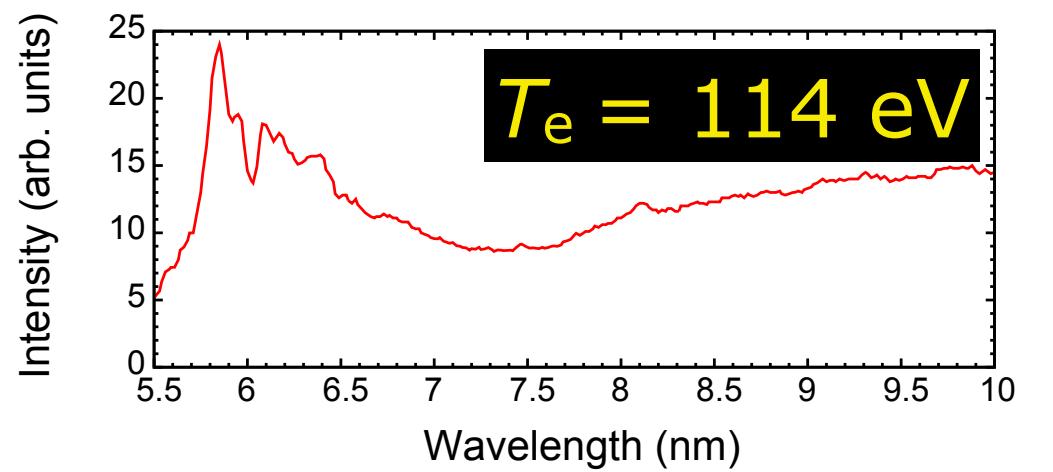
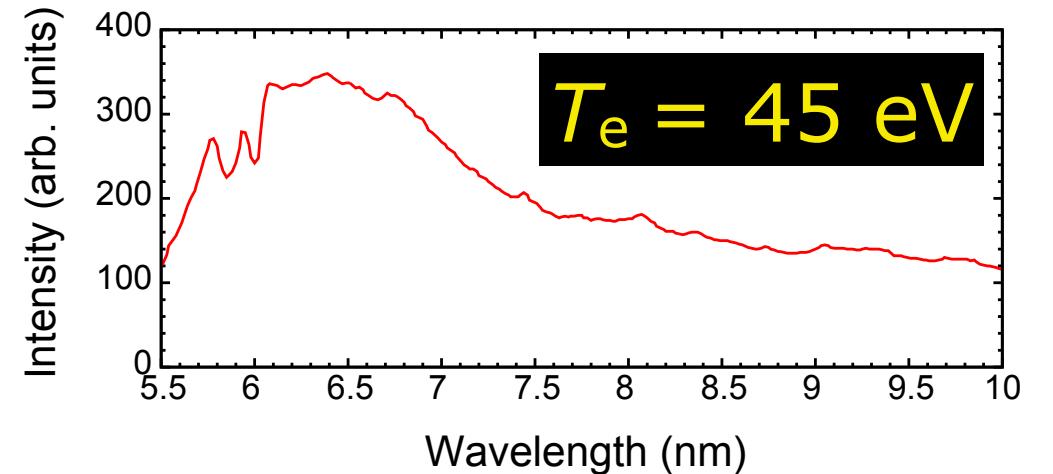
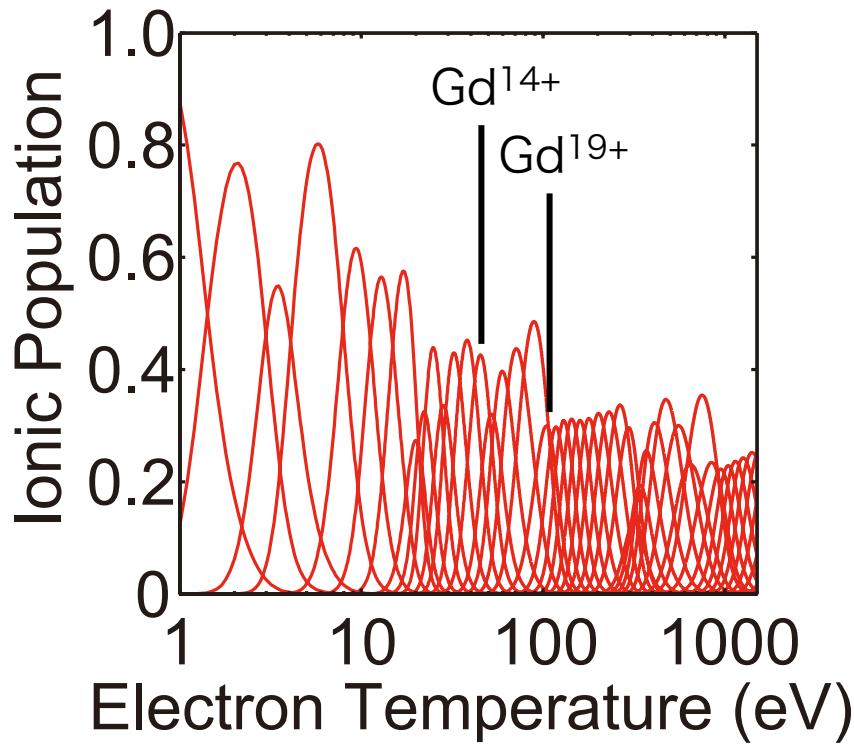


Spot diameter: 210 μm Intensity: $4.0 \times 10^{11} \text{ W/cm}^2$

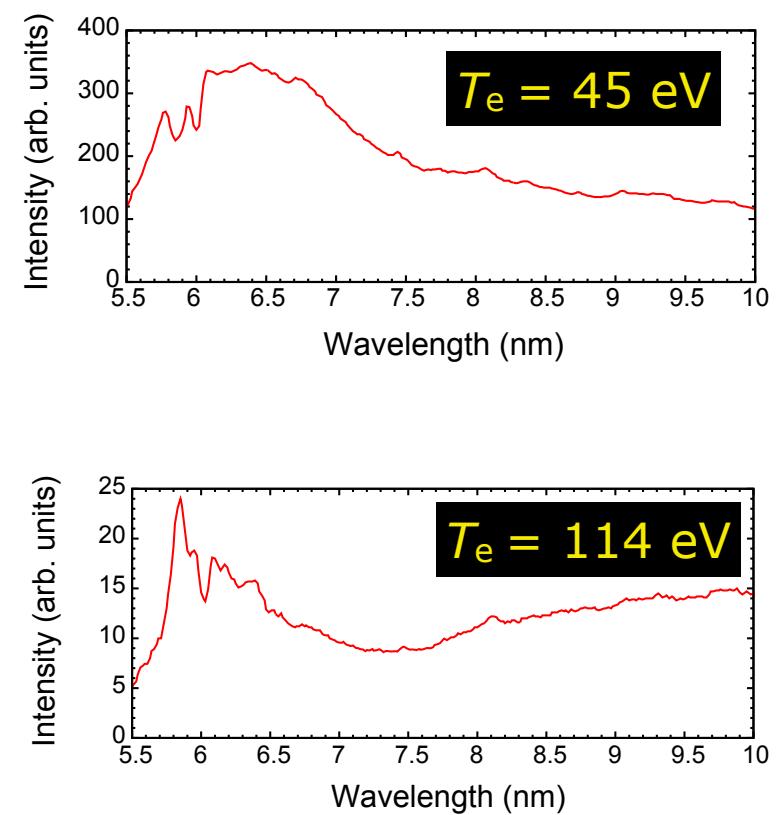
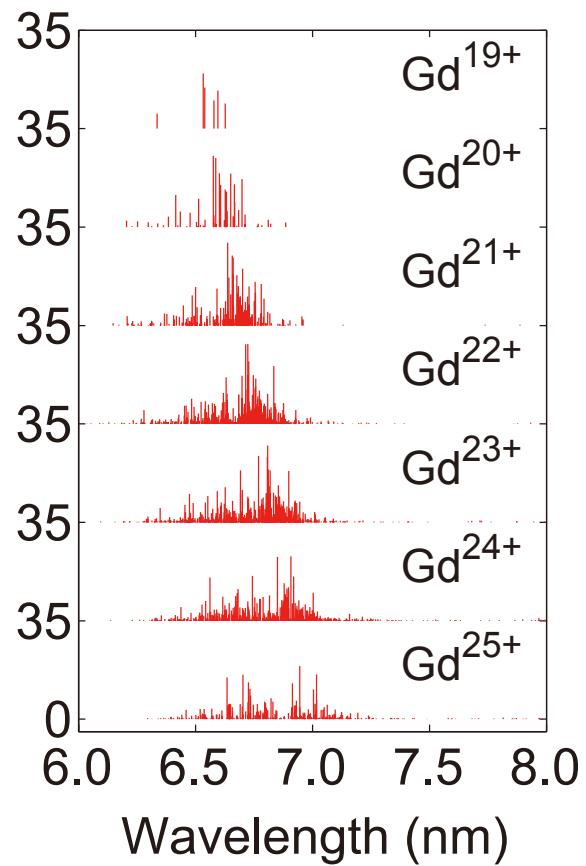
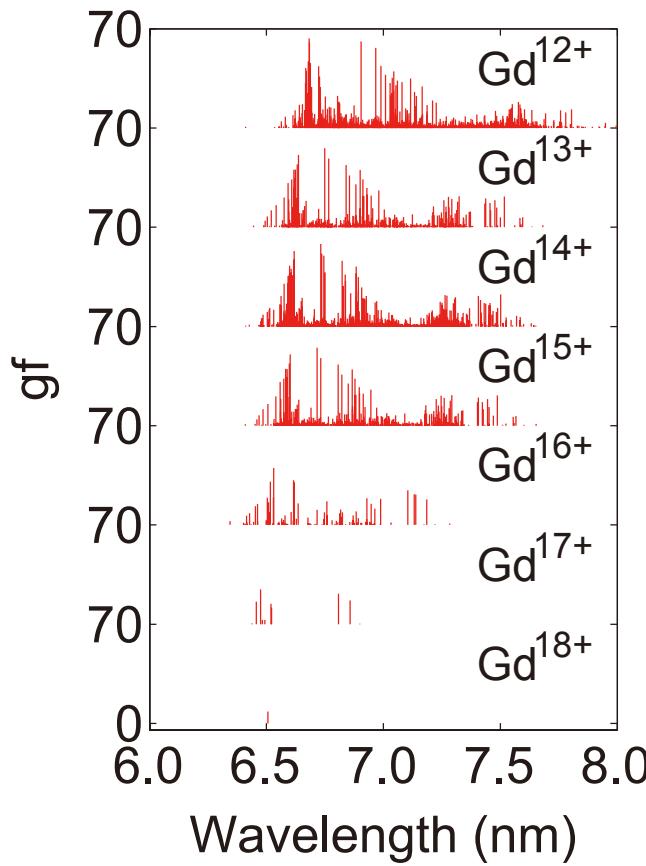


Spot diameter: 35 μm Intensity: $1.5 \times 10^{13} \text{ W/cm}^2$

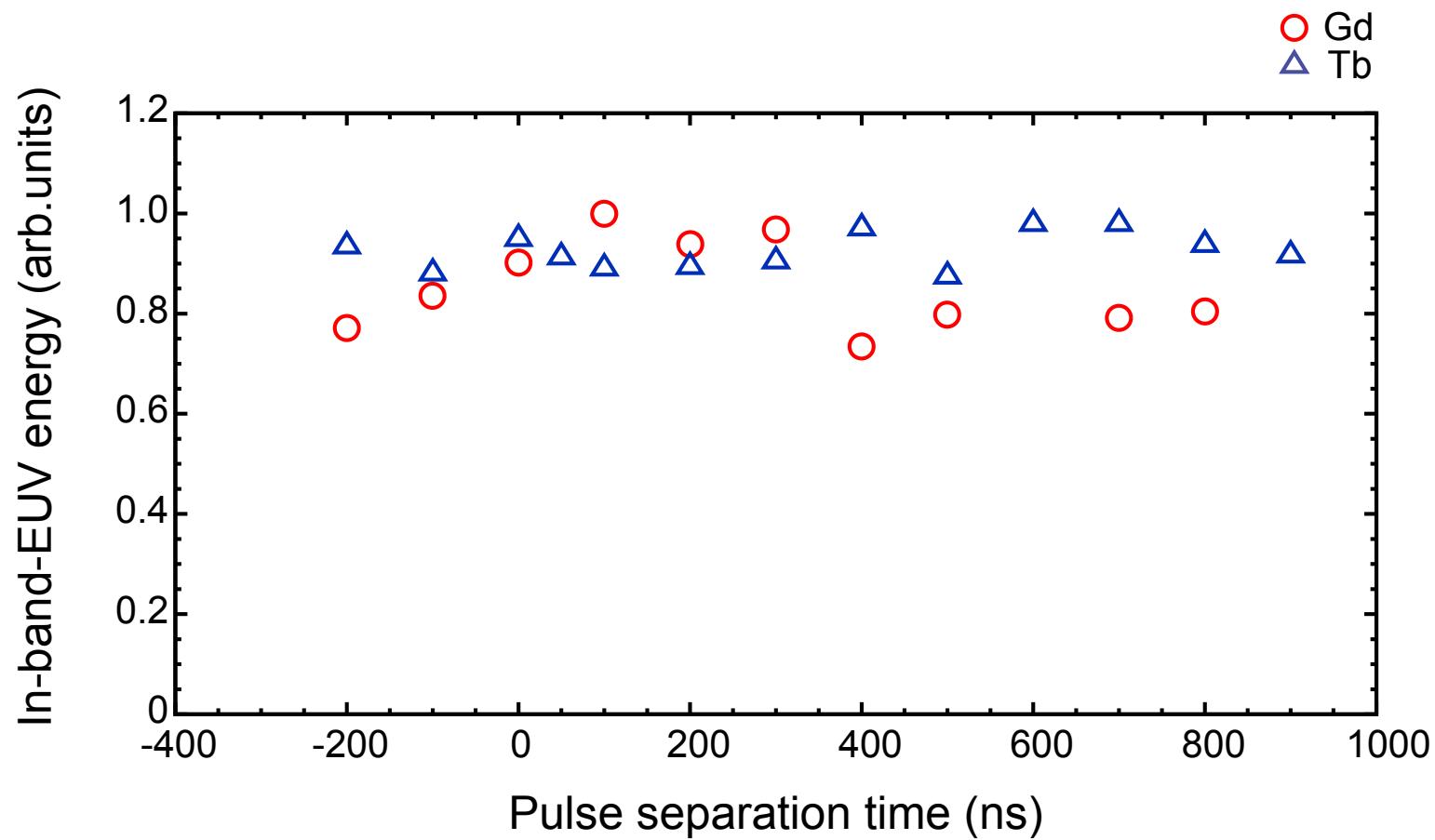
Ionic population



gf spectrum

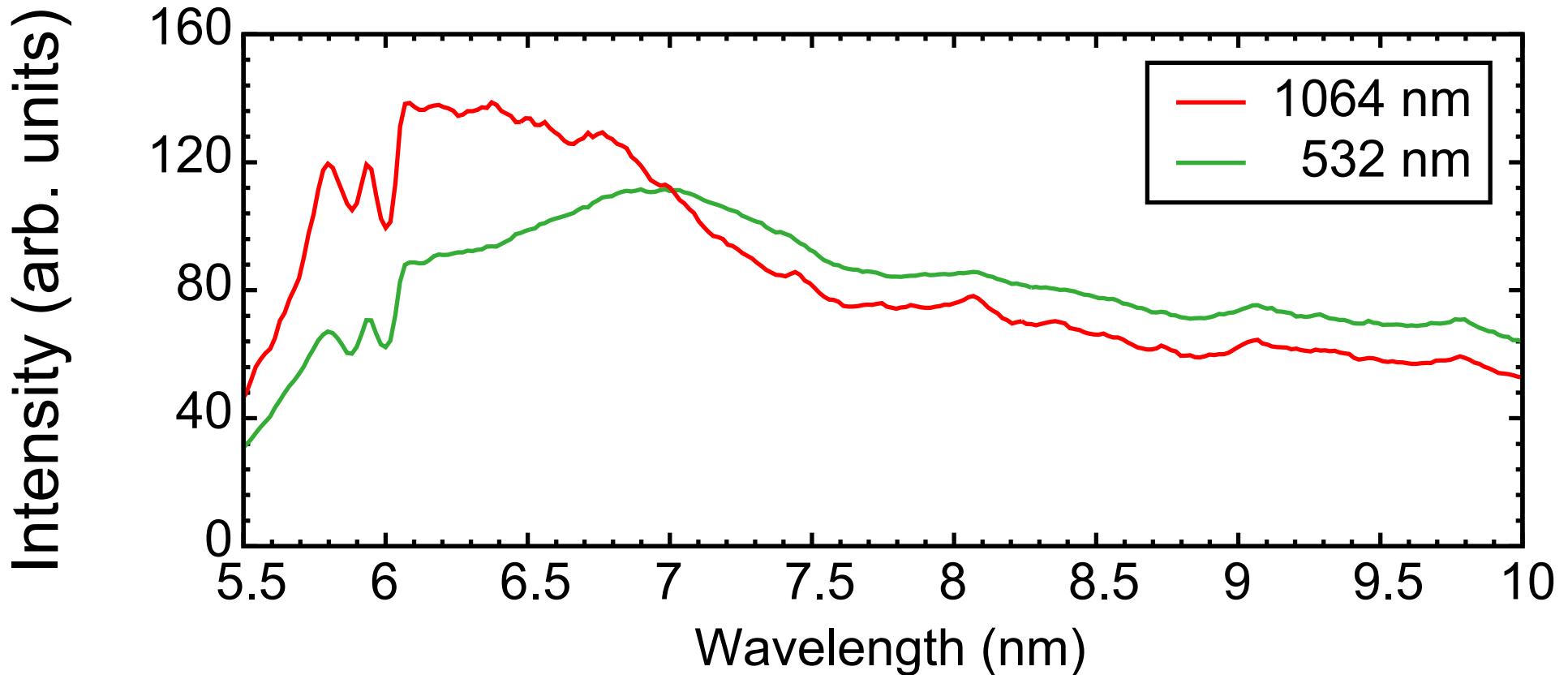


Dual laser pulse irradiation



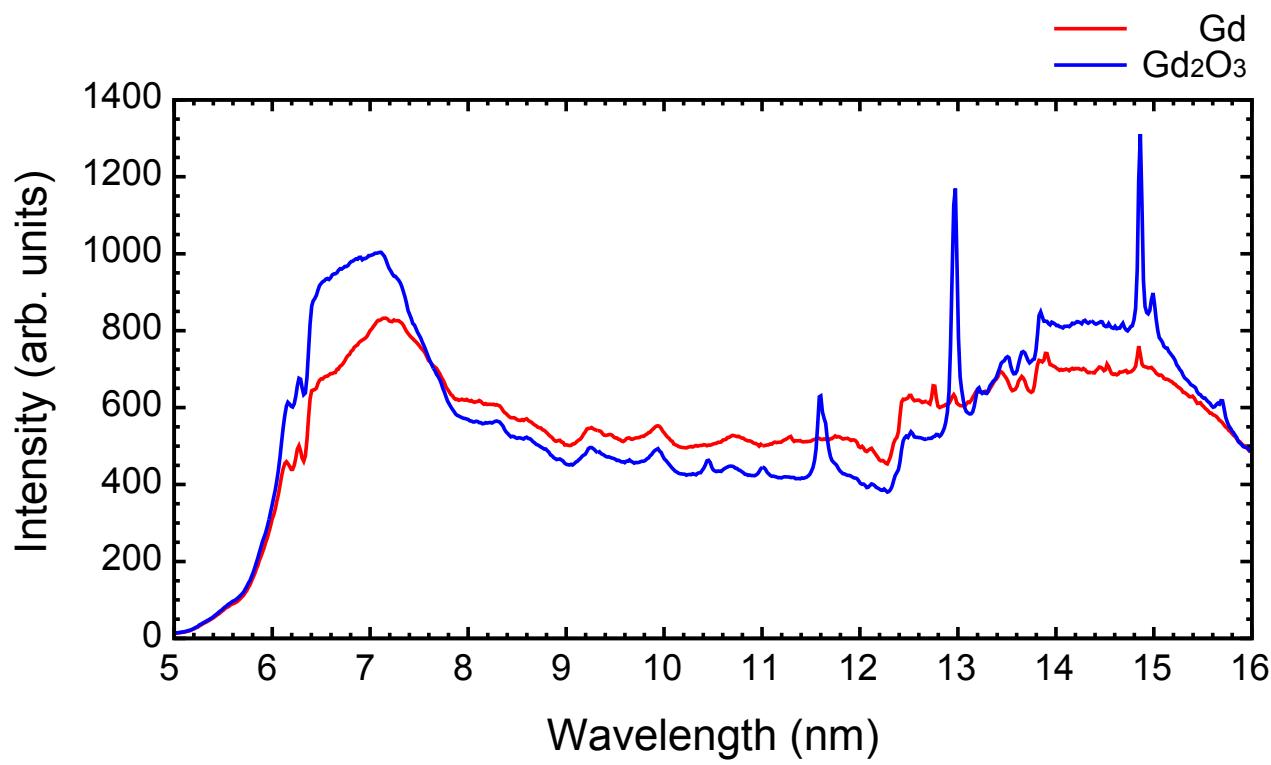
Pre-pulse intensity (532 nm): $3.3 \times 10^{10} \text{ W/cm}^2$
Heating intensity (1024nm): $1.1 \times 10^{12} \text{ W/cm}^2$

Wavelength dependence

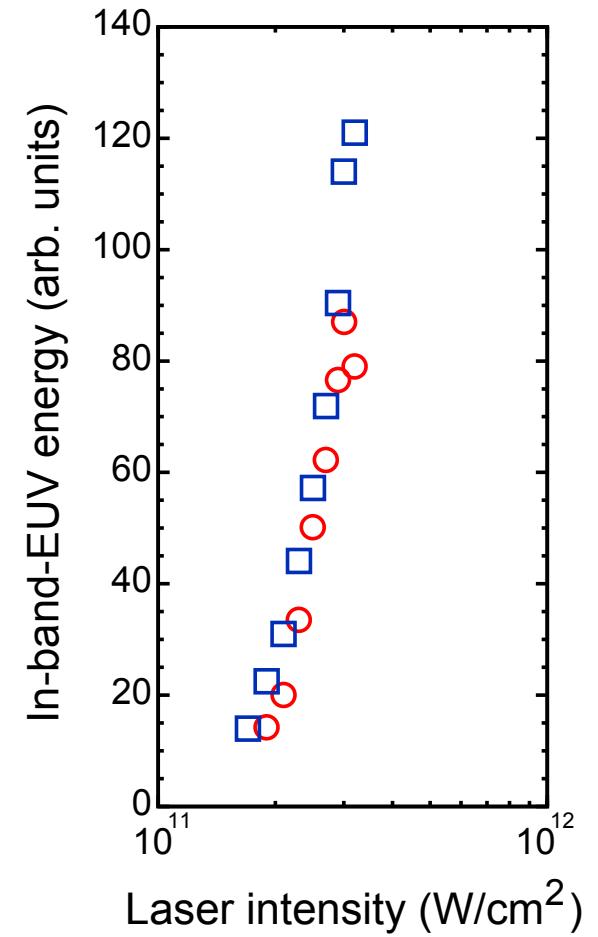


Spot diameter: 160 μm
Intensity: $4.0 \times 10^{11} \text{ W/cm}^2$

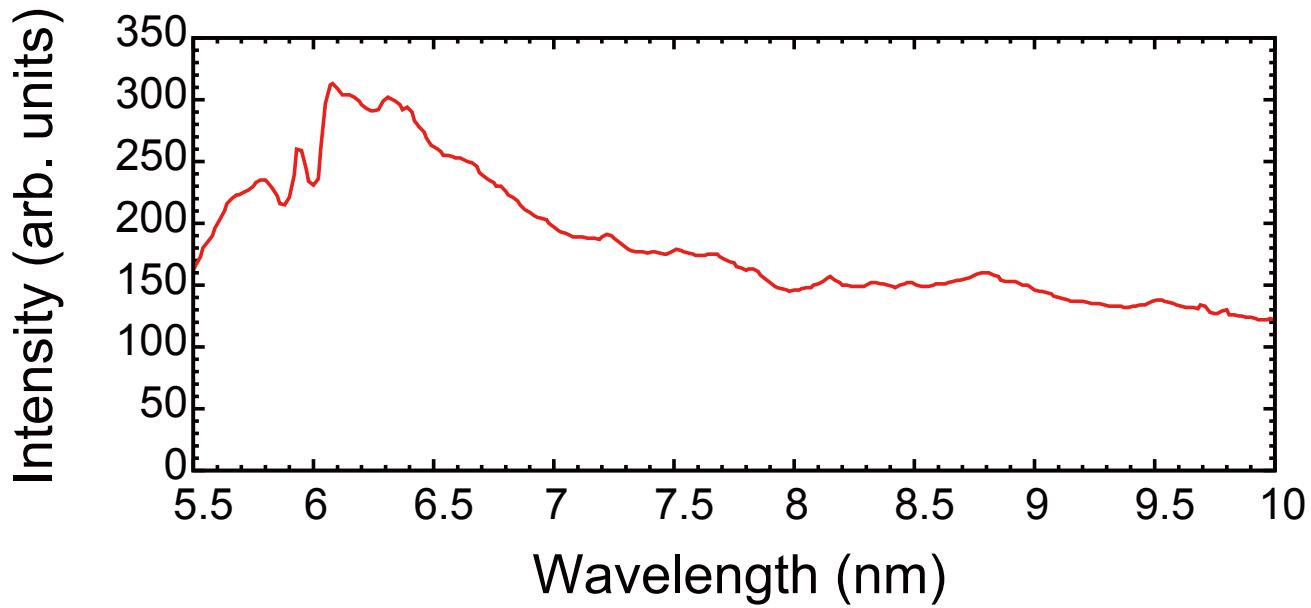
Spectra from low- and solid-density targets



Spot diameter: 200 μm Intensity: $3.2 \times 10^{11} \text{ W/cm}^2$

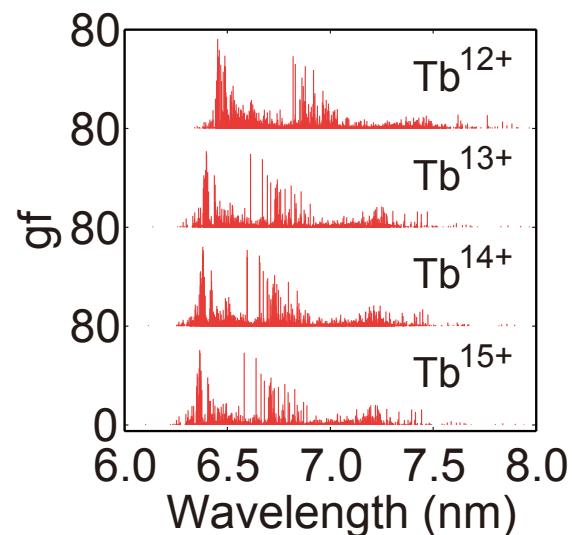
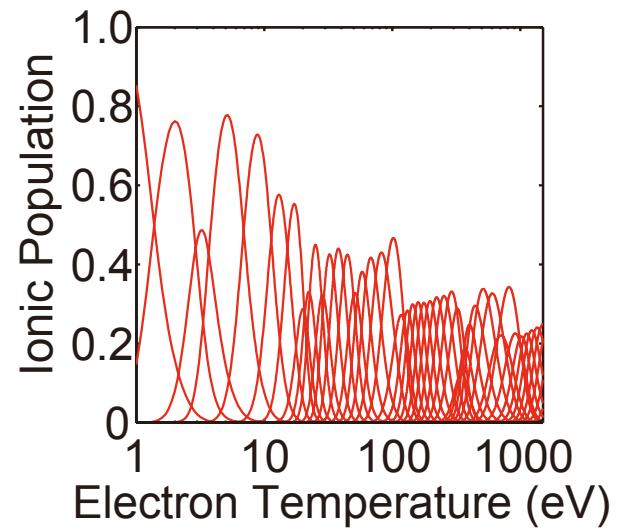


Spectrum from Tb plasma

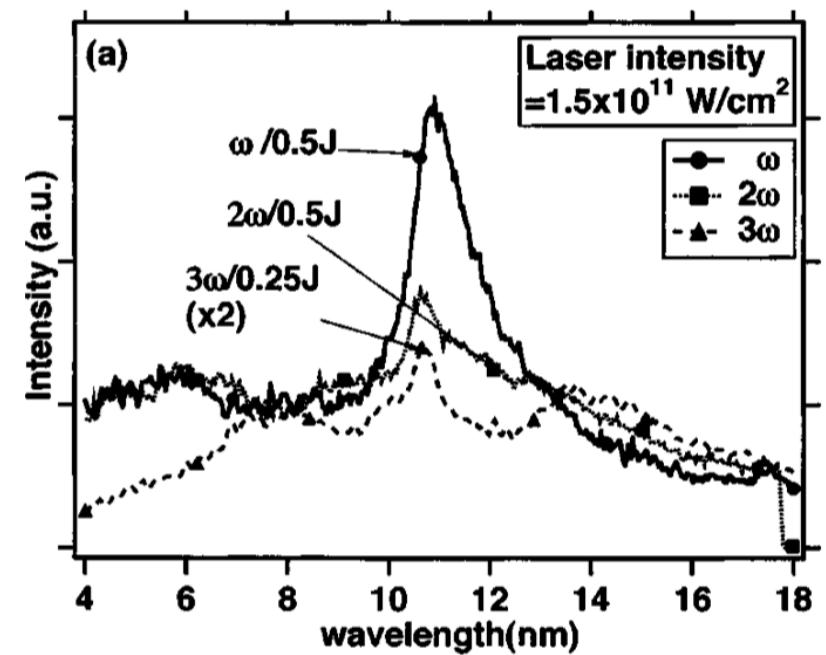
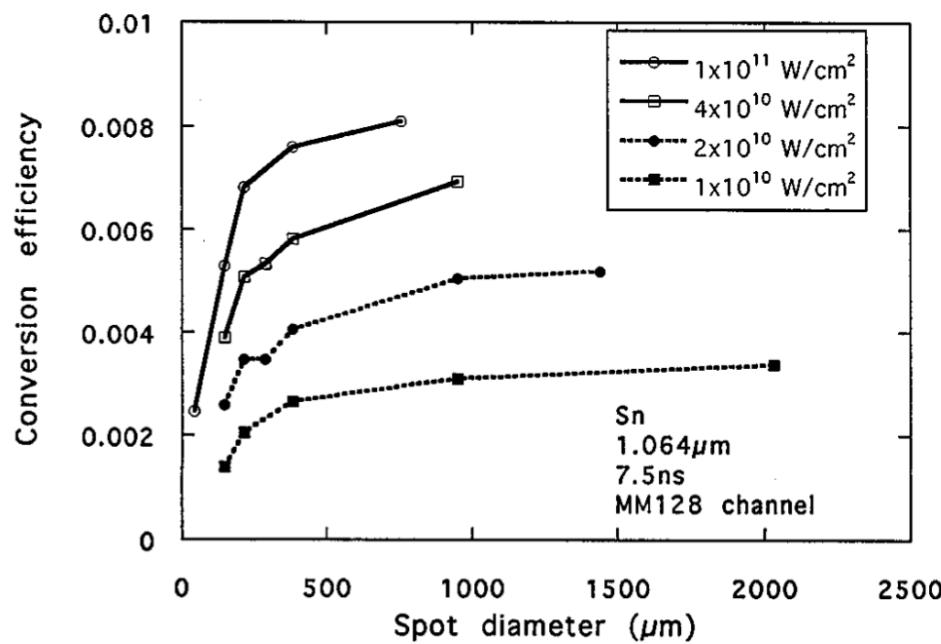


Spot diameter: 210 μm

Intensity: $4 \times 10^{11} \text{ W/cm}^2$



-Discussion- Early evidence - 13.5 nm



R. C. Spitzer *et al.*, J. Appl. Phys. **79**, 2251 (1996)

S. Miyamoto *et al.*, Appl. Phys. Lett. **86**, 261502 (2005)

Summary

**We characterized of EUV emission
from laser-produced plasmas
around 6.5-6.7 nm using Gd and Tb plasmas**

We showed

- spectral behavior.
- enhancement by suppression of the plasma hydrodynamic loss.
- the plasma volume effect dominated
- enhancement by using low density target